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Spruce Budworms Handbook

Silvicultural Strategies To Reduce Stand and Forest Susceptibility to the Western Spruce Budworm

In 1977, the United States Department of Agriculture and the Canadian Department of the Environment agreed to cooperate in an expanded and accelerated research and development effort, the Canada/United States Spruce Budworms Program (CANUSA), aimed at the spruce budworm in the East and the western spruce budworm in the West. The objective of CANUSA was to design and evaluate strategies for controlling the spruce budworms and managing budworm-susceptible forests to help forest managers attain their objectives in an economically and environmentally acceptable manner. The work represented in this publication was partially funded by the Program. This manual is one in a series on the western spruce budworm.

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Silvicultural Strategies To Reduce Stand and Forest Susceptibility to the Western Spruce Budworm

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Introduction

Silvicultural methods can be used to reduce forest and stand susceptibility to western spruce budworm and may be the most effective means of dealing with the insect over the long run. Development of damaging outbreaks ultimately depends on suitable forest habitat, even though the budworm is greatly influenced by climate, weather, parasites, and predators. Suitable forest habitat means that the preferred hosts of budworm, true firs and Douglas-fir, are abundant over large areas in favorable climatic zones. Although we do not know the minimum area needed to sustain an outbreak, conditions obviously are good for budworm throughout much of the Western United States and Canada. Habitat can be altered to the detriment of the insect by silviculturally changing forest and stand conditions. Silvicultural methods provide immediate protection to individual stands that are treated and presumably will provide long-term protection to much larger forested areas when enough area has been treated.

If you decide to use silvicultural strategies to deal with budworm, how should you start? A tremendous amount of budworm habitat exists in the Western United States and Canada, but all habitat is not equally suitable. We have developed a rating system based on factors known or presumed to contribute to habitat quality. The variation in habitat quality can be indexed and provides the land manager with a basis by which to set treatment priorities. This paper presents a brief discussion of those factors, how they are interrelated and integrated into the rating system, and silvicultural methods that will reduce the quality of budworm habitat and maintain forest productivity. In this paper, "susceptible" means that forest conditions are good for producing budworms, that budworm habitat is favorable. Usually, susceptible forests incur significant damage caused by budworm feeding when populations reach outbreak density.

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Factors Affecting Budworm Habitat

Habitat for budworm has increased dramatically since the early 1900's for two reasons. First, the incidence of wildfire today is only a fraction of that before the early 1900's. Second, much of the timber harvesting since settlement of the West removed most of the seral stands—stands that were dominated by pines and larch, conifer species intolerant to shade and not preferred by budworm. Shade-tolerant conifers—such as true firs and Douglas-fir, which are high-quality habitat for budworm—increased substantially. In western Montana alone, hundreds of thousands of acres formerly dominated by seral species, such as ponderosa pine and western larch, are now occupied by late successional or climax budworm hosts. Besides species composition, several other factors interact to affect forest and stand susceptibility: regional climate, intrinsic site climate, stand density, vertical structure, vigor, maturity, and nature of the surrounding forest. Each of these factors will be discussed briefly. Keep in mind that they interact in many ways to affect budworm populations and that no factor is singularly important. Furthermore, we believe that extremely high populations can override factors normally important during periods of lower populations.

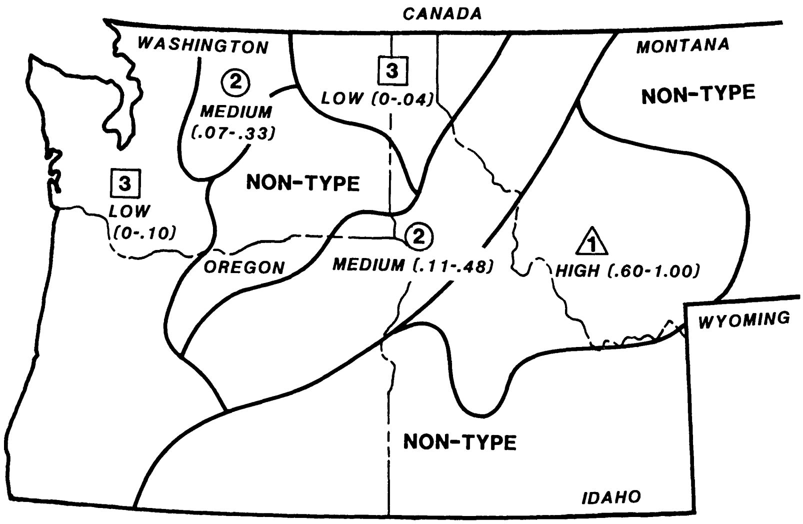

Figure 1—Frequency of budworm outbreaks is related to climate. Class 1 is high frequency, characterized by dry climate; class 2 is medium; and class 3 is low, where moisture is frequent and temperatures are moderate (from Kemp and others 1985).

Regional Climate

Populations of western spruce budworm do well in dry climates where annual precipitation ranges from 9 to 36 inches (23 to 91 cm). Outbreaks are common throughout most montane forests of the U.S. Rocky Mountains, east of the Coast Ranges and into interior southern British Columbia. Outbreaks are uncommon west of the Cascades and in the moist forests of northern Idaho and northwestern Montana, even though extensive host forests are present. Figure 1 illustrates the classes of outbreak frequency (low, medium, and high) during 1948–78 in the Northwestern United States.

Figure 2—Budworm does very well in warm, dry Douglas-fir habitat types where the climax host Douglas-fir is abundant.

Site Climate

Site climate is regional climate modified by the interaction of slope, aspect, elevation, and physiography at a specific location. For example, very dry conditions can exist on steep south-facing slopes in areas otherwise known to have a generally wet climate, and moist sites are known in areas characterized by generally dry climates. Habitat type, the ecological land classification system used throughout much of western North America, is used to index site climate. In areas where general climate is dry, budworm does well on the drier habitat types that support host forests (fig. 2). Alternatively, budworm does poorly in moist, cool, upper elevation habitat types (fig. 3).

Figure 3—Budworm does poorly in cool, moist subalpine fir habitat types, even though abundant host is present.

Species Composition

Stand susceptibility increases as the proportion of host increases. Host conifers for budworm are Douglas-fir, grand fir, white fir, Engelmann spruce, and western larch. The amount of climax host is a key factor influencing susceptibility. Stands composed solely of shade-tolerant host species are highly susceptible, but stands supporting a diversity of seral, shade-intolerant species are less susceptible. The role of a species as host for budworm changes with the successional status of the host species. For example, where Douglas-fir is climax, it is very susceptible to budworm (fig. 2). But on grand fir habitat types in Montana and southern Idaho—where grand fir is the climax conifer—Douglas-fir is seral and, interestingly enough, is much less preferred by the budworm (fig. 4). Genetic resistance to budworm also has been postulated in host populations (McDonald 1981) and may play an important role in budworm dynamics.

Figure 4—When Douglas-fir is seral, such as on this grand fir habitat type, it is not a preferred host by budworm. On these sites, Douglas-fir may be featured in silvicultural plans.

Stand Density

Overstocked, dense host forests are high-quality habitat for the insect (fig. 5). Dispersing larvae are more likely to reach food and shelter than they would in a relatively open stand, increasing the probability of completing their life cycle. Stressed trees, characteristic of overstocking, may also be nutritionally better for feeding larvae, and adults are more likely to find good sites for laying eggs in dense stands. Thus, dense host stands favor expanding populations of budworm, whereas open stands do not. Crown temperatures may be warmer in open stands, however, favoring budworm development.

Stand Height-Class Structure

Multistoried host stands also are good habitat for western spruce budworm (fig. 6). Larvae disperse and move around a lot during feeding, and much of their dispersal is downward. Intermediate crown strata catch many of the dispersing larvae and tend to perpetuate the feeding activity. In stands with only one crown stratum, however, dispersing larvae tend to fall to the ground, where they are consumed by ants, birds, and other predators.

Tree and Stand Vigor

Fast-growing, vigorous trees and stands are not as good habitat for budworm as unhealthy, stagnated stands (fig. 7). Foliage quality is relatively poor for the insect in vigorous, fast-growing trees. Also, fast growers tend to outgrow the effects of heavy budworm feeding and recover faster once an outbreak subsides.

Maturity of Trees and Stands

Susceptibility to western spruce budworm tends to increase as trees and stands mature. Older stands have far greater foliar biomass than young stands and can support much larger populations of the insect. Young even-aged host stands less than 30 years old are poor habitat for the insect: besides having low biomass, they offer little protection to developing larvae. Small budworms are easily sought out and killed by birds, ants, and other predators and are easily dislodged from feeding sites during stormy weather. Conversely, uneven-aged host regeneration growing under the canopy of larger host trees often is heavily damaged by budworm.

Figure 5—Overstocked, stressed host stands incur heavy defoliation and damage from budworm. Foliage quality in these stands likely favors the insect.

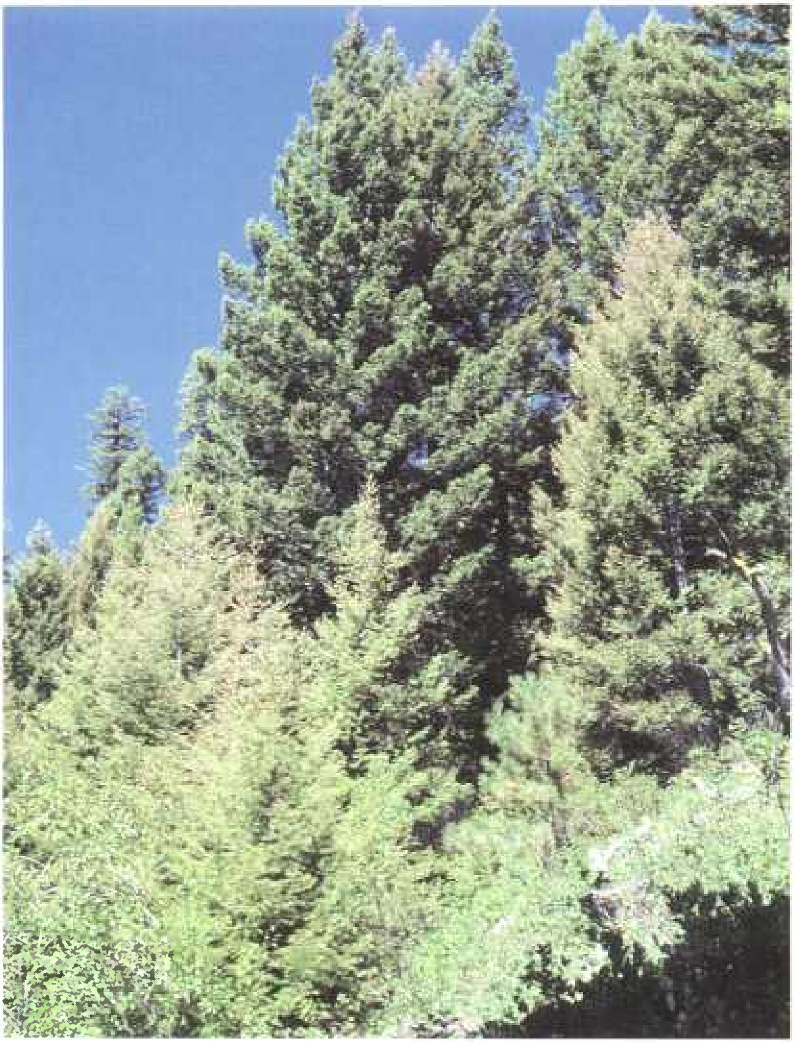

Figure 6—Complex, tiered canopy structures favor western spruce budworm. Larvae disperse often during their feeding period and movement usually is downward. The lower canopy tiers tend to be shade-tolerant host and offer good habitat for larvae dispersing downward, increasing the probability that they will complete their life cycle.

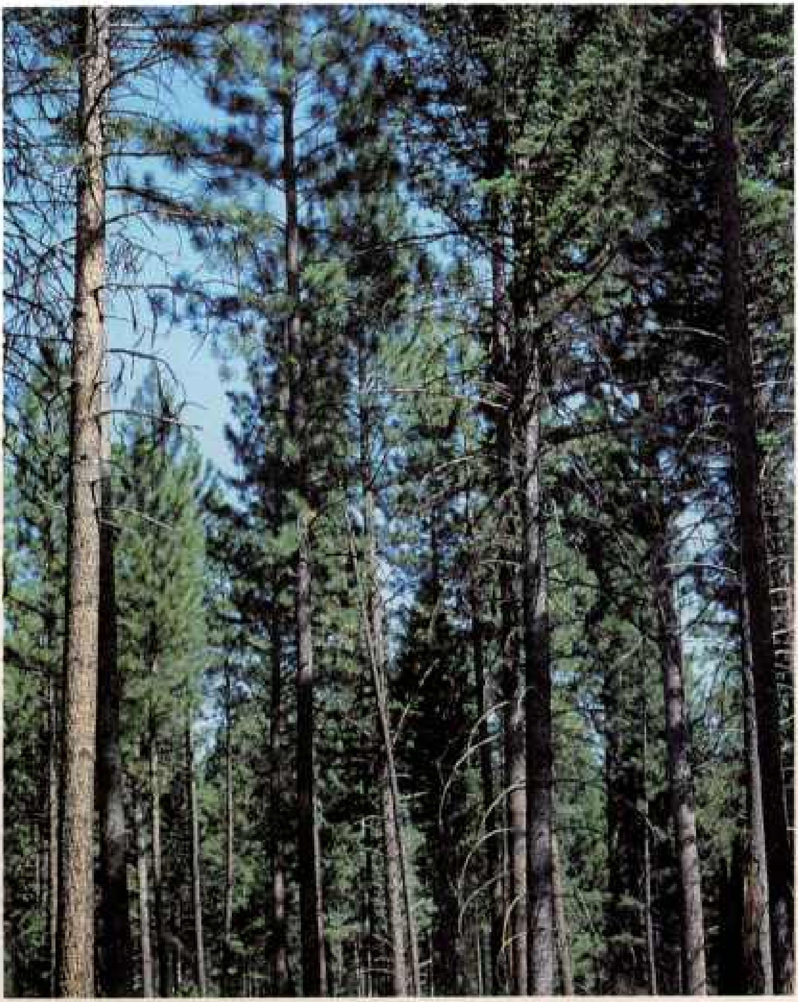

Figure 7—Fast-growing vigorous even-aged stands, even though composed of host species, are less susceptible to budworm than stagnated stands. Foliage quality probably does not favor the insect, and larval mortality is high because during their downward dispersal many do not reach suitable substrate.

Figure 8—Large areas of adjacent host forest increase the susceptibility of a stand to budworm. Even though the stand may be relatively nonsusceptible, it may be inundated by dispersing larvae from the nearby host forest.

Adjacent Host Type

Location and nature of the adjacent forest can be very important to susceptibility of individual stands. Host stands surrounded by or adjacent to nearly continuous host forest are inherently more susceptible than stands adjacent to nonhost or mixed forests (fig. 8). These nearby host forests can produce large quantities of budworms that may inundate an otherwise slightly susceptible stand. Stands downwind of extensive host forest are more susceptible than those upwind.

Rating Stand Susceptibility to Budworm

Susceptibility of stands can be numerically rated by considering the factors that contribute to susceptibility. One method that seems to work well in the northern Rocky Mountains (Wulf and Carlson 1985) is presented here in abbreviated form. This procedure was developed after careful review of published and unpublished literature on budworm biology. The index numbers are best guesses of the relative importance of each of the factors; little definitive work has been done. The method may also work in other parts of the insect's range. Other methods have been tried, but apparently they can be used in very limited locations only (Heller and others 1981, Stoszek and Mika 1983 unpubl.).

The method presented here is fairly simple and easy to use in the field. Possible values for each of the factors are classed, and each class is given an index value. All index values determined for a given stand are multiplied together, and the product of these numbers is the susceptibility index for that stand. Stand indexes can range from 0 for a nonsusceptible stand to 100 for one that is highly susceptible. Ratings from 0 to 20 indicate low susceptibility; 21 to 50, moderate; and more than 50, high. Managers can expect significant defoliation and loss of productivity in stands rated as moderate or high. Damage will not be significant in stands with low susceptibility. The detailed method of Wulf and Carlson (1985) has been automated and can be accessed by personnel of Forest Service Regions 1 and 4. The program uses the timber-stand examination data base, calculates index values, and computes a stand-susceptibility index. Refer to Bousfield and others (1986) for further detail on the automated system.

Factors, Classes, and Index Values

Factor	*Class*	*Index value*
Percent host crown cover in stand	0	0.0
	1–30	0.3
	31–70	1.5
	71–100	2.1
Percent climax host crown cover in stand	0–30	1.0
	31–70	2.0
	71–100	2.4
Stand density (total percent crown cover, all species)	1–40	0.8
	41–80	1.1
	81+	1.4

Factor	*Class*	*Index value*
Height-class structure of stand	1 tier	0.9
	2 tiers	1.5
	3 or more tiers	1.7
Stand vigor (best estimate for the site)	Good vigor	0.9
	Moderate	1.3
	Poor	1.6
Maturity (age, based on dominant and codominant trees)	Seedling/sapling (1–30 years)	0.8
	Immature (31–90 years)	1.0
	Mature (91–140 years)	1.4
	Overmature (140+ years)	1.7
Site climate (habitat-type group or best placement according to class definitions)	Cold subalpine fir, timberline types	0
	Cool, moist spruce and subalpine fir types	0.6
	Warm, moist grand fir; western redcedar; western hemlock; warm, moist subalpine fir types	1.0
	Cool Douglas-fir; cool grand fir; cool, dry spruce; cool, dry subalpine fir types	1.2
	Moist grand fir; warm, moist spruce; moist subalpine fir types	1.3
	Mesic Douglas-fir; dry grand fir; warm, mesic spruce; dry subalpine fir types	1.4
	Warm, dry Douglas-fir types	1.5

Factor	Class	Index value
Regional climate (National Forest or Region with respect to maritime climatic influences)	R-6 and R-5 (west of Cascades)	0.2
	Idaho panhandle (exclusive of St. Joe); Kootenai	0.2
	St. Joe, Clearwater, Lolo (westside), Nezperce (Selway district only), Colville	1.0
	Flathead, Nezperce (other than Selway), Wallowa–Whitman, Umatilla, Malheur, Ochoco, Okanogan, Wenatchee, Boise, Payette, interior British Columbia	1.1
	Bitterroot, Lolo (eastside), Beaverhead, Custer, Deerlodge, Gallatin, Helena, Lewis and Clark, R-4 (except Boise and Payette), R-2, R-3	1.2
Character of adjacent forest	Immature, <50 percent host	0.2
	Immature, >50 percent host	0.5
	Mature, 0–30 percent host	0.8
	Mature, 31–70 percent host	1.4
	Mature, 70+ percent host	1.7

Examples of Susceptibility Rating

Two hypothetical examples serve to illustrate the susceptibility rating method.

	Stand 1		Stand 2	
Factor	*Value*	*Index*	*Value*	*Index*
Percent host	34	1.5	82	2.1
Percent climax host	17	1.0	65	2.0
Density	75	1.1	64	1.1
Height structure	1	0.9	2+	1.7
Vigor	High	0.9	Low	1.6
Maturity (age)	96	1.4	165	1.7
Site climate	Cool Douglas-fir	1.2	Mesic Douglas-fir	1.4
Regional climate	Lolo west	1.0	Lolo east	1.2
Adjacent forest	Mature, 35% host	1.4	Mature, 85% host	1.7

The susceptibility index, SUSIN, for each stand is the product of the factor indexes. For stand 1,

$$\text{SUSIN} = 1.5 * 1.0 * 1.1 * .9 * .9 * 1.4 * 1.2 * 1.0 * 1.4 = 3.14$$

and for stand 2,

$$\text{SUSIN} = 2.1 * 2.0 * 1.1 * 1.7 * 1.6 * 1.7 * 1.4 * 1.2 * 1.7 = 61.01$$

Stand 1 is rated only slightly susceptible, but stand 2 is highly susceptible and affords good habitat for budworm.

Altering Stand Susceptibility to Budworm

Common silvicultural methods will reduce stand susceptibility to budworm. Factors that cannot be manipulated by silvicultural means are regional climate and site climate; those that can be changed are stand composition, density, height-class structure, vigor, maturity, and nature of surrounding forest. These silvicultural treatments can enhance habitat for birds that prey on budworm and seem to fit well with guidelines for increasing birds that feed on the insect (Langelier and Garton 1986). Even-aged or all-aged silvicultural methods may be appropriate, depending on the unique conditions that define a particular stand or forest. Notwithstanding the method used, the objectives in altering stand conditions are to reduce the proportion of host, capitalize on resistant genotypes, regulate stand density so that growth is optimized and vigor is improved, improve conditions for budworm predators, and reduce rotation length. Attaining these objectives will reduce budworm populations to acceptable levels and lower the susceptibility index in managed stands.

Even-Aged Methods

Even-aged silvicultural methods are particularly effective in minimizing budworm habitat. The objective of clearcut, seed-tree, and shelterwood regeneration harvest cuts is to establish even-aged vigorous seral conifer stands. These even-aged methods dramatically reduce susceptibility of the treated stand at the time they are done. All understory conifers are removed either at time of harvest or just before site preparation, and various amounts of the overstory are removed, depending on the type of cut. The clearcut method removes all overstory, seed-tree leaves enough good trees to provide seed for regenerating the new stand, and shelterwood leaves enough trees to provide shelter and seed for the new stand (figs. 9 and 10). The amount of overstory left in the seed-tree and shelterwood methods varies according to intrinsic site conditions, but specific guidelines are beyond the scope of this paper.

Even-aged methods mimic natural ecological processes that operated before the late 1800's, when fire played a dominant role in regulating forest and stand conditions. Stand-replacing fires in effect "clearcut" much of the area burned and prepared the site for conifer regeneration by eliminating competing vegetation and exposing mineral soil. Less intense fires resembled today's seed-tree and shelterwood cuts in that they removed fire-susceptible understory conifer species that are host for budworm, created a few holes in the overstory canopy, prepared the site for regeneration, and favored fire-resistant seral conifers such as ponderosa pine and western larch. Indeed, before 1910 montane forests in the Rocky Mountains were dominated by seral conifers, and outbreaks of the insect were shorter and less intense than today (Anderson 1985).

Figure 9—Clearcutting immediately reduces stand susceptibilty to zero. If seral species seed in naturally or are planted, the future stand will be resistant to budworm.

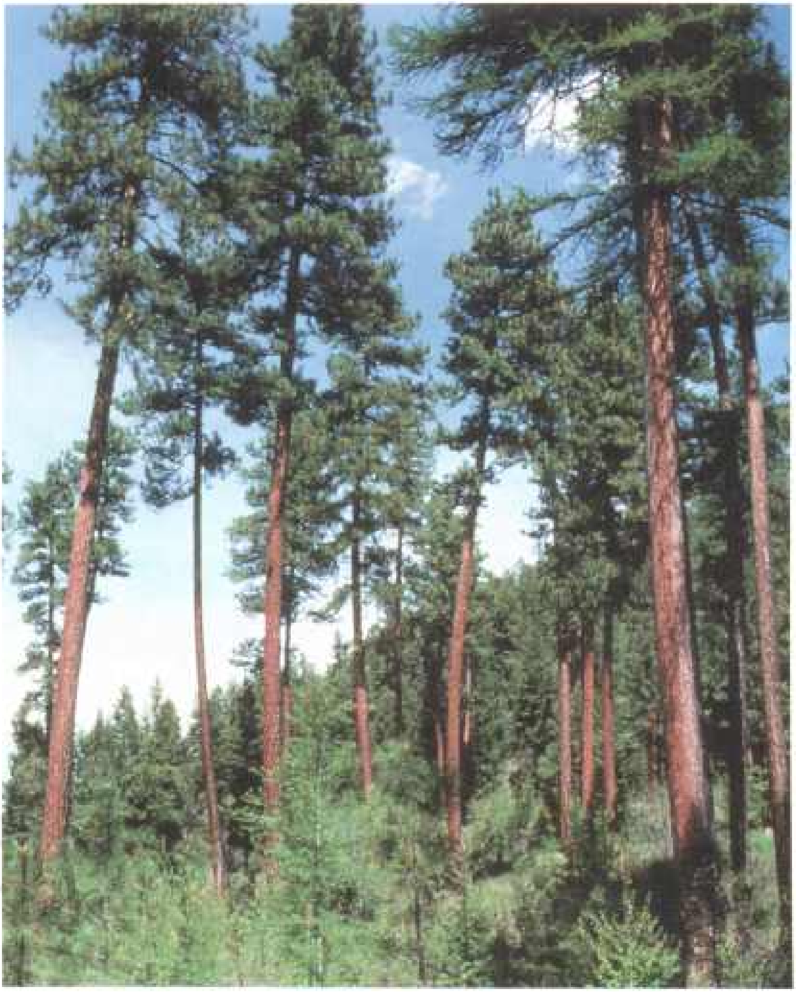

Figure 10—Seed-tree harvest cuts also greatly reduce budworm habitat. Once the new seral, even-aged stand is established, seed trees should be removed.

Often cutover sites can be regenerated by natural seedfall. In poor seed years, however, natural regeneration can fail. Then, the site may need to be planted. Planting gives the silviculturist control over species composition to assure that the future stand will be budworm resistant. The species mix will depend on specific environmental conditions at the site, but generally, we believe that trees in the new stand should not be more than 30 percent climax host species or 50 percent budworm host species overall.

Once desired stocking is attained in the seed-tree and shelterwood methods, the overstory should be removed. Even though the overstory may be nonhost, many larvae can overwinter in bark fissures of the residual trees and may disperse in spring to young trees in the new stand. The hazard is not great, however, because even-aged host regeneration is poor substrate for budworm, and larvae close to the ground are highly vulnerable to predation by ants, birds, spiders, and other fauna. Nevertheless, removal of residual overstory within 10 years of the harvest cut will help protect the new stand.

Density of the new stand should be regulated to optimize growth and development. Species composition can also be influenced so that proportion of host species is maintained at appropriate stocking levels. Studies in Montana have shown that thinning will increase stand vigor, increase budworm larval mortality by increasing dispersal losses, and further reduce the amount of host material or habitat (Carlson and others 1985b). Caution is advised, however. Boyd Wickman (personal communication) noted in eastern Oregon that when budworm populations were exceedingly large, thinned trees had higher budworm densities and more damage than unthinned. A first-entry, precommercial thinning may be warranted between 20 and 30 years after harvest. Resulting stand density will depend on various site and economic factors at the time of thinning. A second entry may be made between 50 and 60 years. This thinning should create some revenue and will reduce stand susceptibility to budworm.

Uneven-Aged Methods

Uneven-aged silvicultural methods can be used against budworm, but only in certain habitats. On dry habitat types of the Douglas-fir forest climax series, ponderosa pine often is the only alternative conifer species. In these stands, most of the Douglas-fir and the suppressed and intermediate pine should be removed at harvest. Light ground fire, either in early spring or late fall, or spot burning of slash will prepare the site for natural or planted pine regeneration. Removal of the fir and suppressed and intermediate pine should create canopy openings so that plenty of light will be available for the shade-intolerant pine seedlings. This method will result in nearly pure uneven-aged ponderosa pine stands on these dry Douglas-fir habitats—stands that will be budworm-proof.

Uneven-aged methods probably would not be effective against budworm on warm, moist habitats because shade-tolerant species that are principal budworm host would flourish and would be difficult to regulate. In very cool, moist habitats, however, such as high-elevation subalpine fir habitat types, where budworm cannot do well, uneven-aged methods may be practical for reasons other than budworm management.

In the cool, dry, Douglas-fir habitat types found east of the Continental Divide in Montana and Idaho, seral conifer species often are lacking. Douglas-fir may be the only available species. In these stands, species conversion likely is not an alternative; therefore, susceptibility to budworm must be reduced by regulating stand density, vertical structure, and age. These types of stands are usually highly susceptible to budworm, perplexing to manage, and afford minimal silvicultural opportunities to affect budworm populations.

Intermediate Cuts in Existing Stands

Throughout much of the range of western spruce budworm, many host stands are not ready for regeneration harvest cuts. These stands exist today because the old-growth seral stands were harvested in the early 1900's with little thought of the character of the succeeding stand. Fire was controlled, and the shade-tolerant species that are budworm hosts took over. These stands now provide a tremendous amount of habitat for the insect. Most of them are overstocked, of questionable vigor, and multistoried. For example, hundreds of thousands of acres in the Douglas-fir and grand fir habitat types in the northern Rocky Mountains of Montana and some parts of southern Idaho support nearly pure stands of Douglas-fir or grand fir where western larch and ponderosa pine formerly dominated. Given 2 or 3 consecutive years of warm, dry spring weather, and other conditions suitable for the insect, budworm outbreaks can occur quickly and cause significant damage to the resource.

Intermediate-aged host stands can be thinned to improve stand vigor, reduce amount of host biomass, and increase mortality of dispersing larvae (fig. 7). In a western Montana Douglas-fir stand about 75 years old, reducing density to about 200 to 300 trees per acre reduced percent defoliation and allowed affected trees to recover. Similar observations were made in grand fir stands in central Idaho. Only the most vigorous dominant and codominant trees should be left on the site. All understory should be slashed. Depending on the size of material and existing markets, some revenues may be generated by these intermediate cuts. More often, the treatment will have to be considered an investment to reduce future losses.

Strategy for Reducing Forest Susceptibility to Budworm

Silvicultural treatments can significantly reduce susceptibility to budworm in individual stands. Harvesting a mature overstory of host and regenerating the stand to nonhost species is very effective. How overall forest susceptibility can be decreased is also of concern. A systematic approach may offer some hope.

A budworm-susceptible forest may cover a significant amount of topography, including several major drainage systems. Many conifer stands of varying character exist in any one drainage; these stands should be rated and ranked for susceptiblity to the insect. The most susceptible stands should be harvested first, followed by those with less risk. Eventually, the drainage will support a mosaic of even-aged stands of varying ages composed mostly of nonhost conifer species. Meanwhile, forest susceptibility will be reduced somewhat by altering the most susceptible stands first. As more and more drainages are treated, the forest will become less and less susceptible. This simple idea may seem easy enough at first glance, but other constraints on timber harvesting may override budworm considerations. Even so, every effort should be made to account for budworm in the future forest. Significantly, a large amount of good budworm habitat is protected by Federal law from harvesting. These stands exist in designated wilderness, National Parks, and other special areas. They developed after fire was virtually eliminated from those areas. Budworm-susceptible stands in protected areas will continue to be a refuge for the insect. Currently, forest managers are developing plans to restore fire to its natural role in those areas. If they are successful, a large amount of budworm habitat could be eliminated (fig. 11). Certainly the hazard posed by budworm-susceptible forests in wilderness should be addressed when developing these plans.

Figure 11—Prescribed fire reduces the amount of understory host and can be effective in reducing susceptibility to budworm in wilderness areas.

Summary

In areas where western spruce budworm is a problem, stands should be rated for susceptibility to budworm and ranked in priority for treatment. The following are silvicultural practices that will reduce budworm habitat and sustain vigorous forest growth:

- Strive for stand diversity in species composition by favoring seral trees and removing or otherwise discriminating against the most shade-tolerant host species.
- Regulate stand density through appropriate release cuttings and thinnings to improve and maintain tree vigor and stand growth.
- Create and maintain even-aged stand structures by using even-aged regeneration systems, followed by periodic low and crown thinnings.
- Promptly remove all overstory trees once regeneration is established in seed-tree and shelterwood cuttings.
- Improve stand vigor by removing diseased, heavily infested, or otherwise unhealthy trees in all cuttings.
- Capitalize on phenotypic and genetic resistance to budworm by selecting the most heavily defoliated trees for removal. Retain the lightly or nondefoliated trees for seed trees; direct cone-collection programs to those phenotypes.
- Regenerate host stands to less susceptible species at or before biological maturity as indicated by the culmination of mean annual growth.
- Diversify the host forest by creating seral stands in homogeneous areas of late successional or climax host stands.

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